M.R.P. 971
S.C. 111/201
9th April, 1956

Variation of visibility in fog at Exeter Airport, and the time of fog dispersal

by

W.E. Saunders
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METEOROLOGICAL
OFFICE
- 5 OCT 1956
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M.R.P. No. 971 by Mr. W.E. Saunders
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Summary

An account is given of the variation in visibility at Exeter Airport during periods of fog. Main features of interest are the rapidity with which visibility falls to lower values within the fog range once fog has formed, the effectiveness of cloud cover as a fog-clearing agency, and the comparatively regular intervals between times of clearance of fog during the morning, and times of sunrise.

The site and observational programme

The airfield lies in a shallow basin formed by the high ground of Dartmoor to the southwest and west, Exmoor to the north, and the Blackdown Hills to the east. There are no intervening hills between the airfield and the English Channel to the south and the Exe Estuary to the southwest.

The only significant source of local smoke is the city of Exeter, some three miles west of the airfield.

The situation of the airfield is shown in Fig. 1.

The normal hourly and special observations of a synoptic station were made at Exeter throughout the period from which data have been used in this study. Additional temperature readings, which have been included in the notes on clearance of fog beneath cloud, were as follows:-

(i) Hourly readings of the grass minimum thermometer used as an ordinary thermometer at grass level, and of a bent stem earth thermometer with the bulb at a depth of 2 in.

(ii) Twice-daily readings of a bent stem earth thermometer with the bulb at 8 in. These readings were made at 0900 and 2100 GMT.

Type of fog at Exeter

The fog was predominantly water fog as defined by Corby and Saunders (1); that is fog which did not form until after the relative humidity exceeded 95%. The investigation covers 145 cases (i.e., all the occasions of radiation fog) over the period September, 1953 to December, 1955. On only ten of these occasions did visibility enter the fog range with relative humidity less than 95%, the lowest being 93%. The results described therefore apply only to water fog. It is considered unlikely that they will apply to smoke fog, or to water

/fog

fog containing a high smoke content. They may, however, be of interest to forecasters at other rurally placed stations, or to stations which experience "clean" fog when the airstream is moving from some known direction.

Time taken for visibility to fall below certain limits

The variation in visibility following the initial report of fog was studied in all cases (112 out of 145) in which fog-clearing agencies were not at work. The cases omitted were those in which there was freshening wind, cloud cover, frontal passage, or which occurred at the end of the night.

Variations in visibility were examined in terms of the time taken to fall to "550 yd. or below", and to "220 yd. or below". On some occasions fog-clearing influences became apparent soon after the 550 yd. stage was reached, but there were 92 occasions suitable for examination in regard to the 220 yd. limit.

The overall picture is given in Table I.

Table I - Time for visibility to fall below 550 or 220 yd.

	Hours, from initial report of fog					
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	Not reached
For visibility to fall to 550 yd. or below	96	11	1	0	0	4
For visibility to fall to 220 yd. or below	47	21	6	6	1	11

Table I emphasises the rapid fall of visibility in water fog. On 95% of occasions visibility is 550 yd. or less within two hours of fog formation. The transition to dense fog is sometimes rather less rapid, but on 74% of occasions visibility is 220 yd. or below within two hours.

The rate of decrease of visibility was examined in relation to certain initial conditions which might have influenced the result. These were the initial fog point temperature and the rate of fall of temperature while the visibility was falling, the wind direction, the visibility preceding fog formation, and the state of ground. An account of these is given in the following paragraphs.

Variation with temperature

The rate of decrease of visibility was examined in conjunction with the fog point, i.e., the temperature at which water fog formed, and the results are given in Table II. This shows that the four cases included in Table I as failing to reach the 550 yd. limit were all on occasions when the initial fog point was below 40°F. Otherwise the table is not very conclusive. Dense fog may still be expected when the fog point is several degrees below freezing.

/Table II

Table II - Time taken for visibility in fog to fall below certain limits - variation with fog point temperature

Fog point °F.	Hours, from initial report of fog, for visibility to reach 550 yd. or less				Hours, from initial report of fog, for visibility to reach 220 yd. or less					
	0 - 1	1 - 2	2 - 3	Not reached	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	Not reached
60-64	3	1	-	-	2	1	1	-	-	-
55-59	5	-	1	-	3	-	-	2	-	-
50-54	21	2	-	-	11	3	1	1	-	2
45-49	27	2	-	-	9	10	2	1	-	2
40-44	19	3	-	-	11	4	1	-	-	3
35-39	11	2	-	2	6	1	1	-	1	2
30-34	7	1	-	1	4	2	-	-	-	1
25-29	3	-	-	1	1	-	-	2	-	1

Table III - Fall of temperature, from fog point, for visibility to reach certain limits

Fog Point °F.	Fall of temperature, from fog point, for visibility to reach 550 yd. or less, °F.						Fall of temperature, from fog point, for visibility to reach 220 yd. or less, °F.					
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6
60-64	2	1	1	-	-	-	1	-	1	2	-	-
55-59	3	1	-	2	-	-	1	1	-	2	1	-
50-54	16	3	1	2	1	-	8	3	1	3	1	-
45-49	24	1	1	-	1	2	11	1	4	1	1	4
40-44	16	4	1	-	1	-	6	7	3	-	-	-
35-39	8	2	2	1	-	-	5	1	1	-	2	-
30-34	7	1	-	-	-	-	4	1	1	-	-	-
25-29	2	1	-	-	-	-	2	-	-	1	-	-

/Table

Table III shows the further fall of temperature, once fog has formed, for visibility to reach 550 yd. or less, and 220 yd. or less. This shows that while, in general, only a slight fall of temperature amounting to a degree or so is required, there are a few occasions on which the fall is as much as five or six degrees. It might be expected on theoretical grounds that these would be the low temperature occasions, but this is not borne out by the table.

Variation with visibility before fog formation

In order to determine whether there was any connection between the rate of fall of visibility preceding fog and in the fog, the rate of decrease of visibility was compared with the visibility three hours before fog formation, and the results are given in Table IV.

Table IV - Time taken for visibility in fog to fall below certain limits - variation with visibility three hours before fog formation

Visibility 3 hours before fog formation	Hours, from initial report of fog, for visibility to reach 550 yd. or less				Hours, from initial report of fog, for visibility to reach 220 yd. or less					
	0 - 1	1 - 2	2 - 3	Not reached	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	Not reached
Over $6\frac{1}{4}$ mi.	27	2	-	1	15	7	1	-	-	3
$2\frac{1}{2}$ - $6\frac{1}{4}$ mi.	36	5	-	-	15	7	3	3	1	5
2200 yd.-$2\frac{1}{2}$ mi.	18	3	-	3	12	6	1	-	-	3
1100-2200 yd.	15	1	1	-	5	1	1	3	-	-

Table IV shows that there is some tendency for hazy initial conditions to be followed by a rather slower deterioration than when fog forms in clean air.

Variation with wind direction before fog formation

The time taken for visibility to fall to the prescribed limits was compared with the wind direction three hours before the time of fog formation, as shown in Table V.

/Table V

Table V - Time taken for visibility in fog to fall below certain limits - variation with wind direction three hours before fog formation

Wind direction 3 hours before fog formation (degrees)	Hours, from initial report of fog, for visibility to reach 550 yd. or less				Hours, from initial report of fog, for visibility to reach 220 yd. or less					
	0 - 1	1 - 2	2 - 3	Not reached	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	Not reached
001-030	4	1	-	1	1	2	-	-	-	1
031-060	4	3	-	-	2	2	-	1	1	1
061-090	2	-	1	-	1	1	-	1	-	-
091-120	6	-	-	-	2	1	-	1	-	1
121-150	7	-	-	-	5	-	-	-	-	-
151-180	11	2	-	-	8	3	1	-	-	-
181-210	2	-	-	-	2	-	-	-	-	-
211-240	4	-	-	-	2	1	-	-	-	-
241-270	3	-	-	-	2	-	1	-	-	-
271-300	2	-	-	-	-	1	-	-	-	1
301-330	9	1	-	-	2	1	2	-	-	1
331-360	1	-	-	2	-	-	-	-	-	2
Calm	41	4	-	1	20	9	2	3	-	4

The large proportion of "calms" renders analysis of Table V difficult, but perhaps some tentative conclusions may be drawn. The most significant feature seems to be the rapidity of decrease of visibility with wind direction bringing moist air from the English Channel and Exe Estuary. Thus, in all cases with wind direction between SE. and W. (through S.) the visibility was 550 yd. or less within two hours, and 220 yd. or less within three hours, of fog formation.

Variation with state of ground

The times for visibility to reach the agreed limits were compared with the reported state of ground before fog formation. The results, given in Table VI, show that in all cases of wet ground visibility fell to 550 yd. or less within two hours of fog formation, and that wet ground much reduces the chance of visibility 220 yd. or less not being reached.

Table VI - Time taken for visibility in fog to fall below certain limits - variation with state of ground before fog formation

State of ground before fog formation	Hours, from initial report of fog, for visibility to reach 550 yd. or less				Hours, from initial report of fog, for visibility to reach 220 yd. or less					
	0 - 1	1 - 2	2 - 3	Not reached	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	Not reached
Dry	50	2	1	4	23	11	4	3	-	9
Wet	46	9	-	-	24	10	2	3	1	2

The effect of cloud cover on fog

The effect of cloud cover on existing fog was examined. The criteria adopted were that the cloud amount, excluding broken cirrus, should increase from four oktas or less to five oktas or more, or that an existing cloud sheet should lower significantly. The effect of cloud cover on the fog is shown in Table VII.

Table VII - The effect of cloud on fog

	Fog cleared. Time taken from increase in cloud for visibility to increase to 1100 yd. or more (hours)					Fog did not clear
0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	
18	11	4	2	4	1	10
	(number of occasions)					

Table VII shows that to a marked extent water fog is dispersed by any appreciable cloud cover. This applied on 40 out of 50 occasions, and on nearly half the nights when fog cleared it did so within one hour of the cloud arriving or increasing.

The temperature distribution during the fog preceding the arrival or increase of cloud was always of the same type. The lowest temperature of those measured was at the grass level. Of the soil temperatures at -2 in. and -8 in. the latter was always the higher. The screen temperature was intermediate between the grass and -2 in. temperatures. After the arrival of cloud the most pronounced change was at grass level. This temperature always increased, in some cases by as much as 10 or 12°F. At both screen level and -2 in. changes were slight, often less than ±1°F. After clearance of the fog, readings of grass and screen temperatures were usually nearly the same, though sometimes there was still an inversion between them.

Example

Date	Time	Wind	Cloud	Visibility	Temperatures Screen	Grass	-2 in.	-8 in.
18/11/53	2356	Calm	Nil	160 yd.	42.2	40.9	46.7	48.8°F.
19/11/53	0156	Calm	8/8	1800ft.1800 yd.	44.9	44.3	47.2	-

The records of all the foggy nights affected by cloud were examined to see to what extent the result was affected by height of cloud. This showed that on all occasions when the cloud base was not above 2500 ft. the fog cleared. Most of these cases cleared within two hours of the arrival of cloud, but in one instance the process required 5-6 hours. The effects of medium and high cloud and of higher stratocumulus were much less regular. The records of cases in which fog failed to clear under cloud contained some suggestion of W. or NW.'ly drift at some stage in most of them; this might imply some smoke content from Exeter. The investigation leaves a strong impression that clean water fog is readily cleared by cloud, and that if the cloud is not above 2500 ft. the process is likely to be rapid.

/The

The time of clearance of fog

In the absence of other fog-clearing influences, such as freshening wind or increasing cloud cover, the time of clearance should be roughly determined by the amount of insolation, which varies with the date, and by the vertical thickness of the fog. In the absence of measurements of the depth of fog some guidance is given by the appearance of the fog from the ground, whether it is reported as "sky obscured" or "sky visible".

In Fig. 2, for which the period was extended to 1939-1955, the intervals between times of sunrise and of fog clearance have been plotted against the date, and separated according as the sky was or was not visible at 0600 GMT. This time was selected partly because it marks a stage at which, taking the year as a whole, cooling is practically completed, and partly because it is a convenient time in relation to the issue of short-term forecasts on which many day-time activities depend. Occasions when the fog formed after 0600 were plotted as "sky visible" regardless of whether it later became obscured. Occasions omitted were those in which cloud appeared to affect the result, or where there was freshening wind. The number of occasions was sufficient to draw the mean curves AA and BB with fair accuracy, except in mid-winter. The minimum time interval between sunrise and fog dispersal occurs in spring, and this is perhaps due to a somewhat lower water content in fogs at this season as compared with summer and autumn. A small number of "sky visible" cases was noted in January-March in which the original fog point was below 32°F. and the clearance time mostly before sunrise. The fog point temperature has been inserted against these cases in Fig. 2, and they have been disregarded in drawing BB. Presumably the fog clearance in these cases was due to deposition of the moisture as frost.

Fig. 2 shows that a substantial proportion of fogs cleared within one hour of the times indicated by AA and BB. It is not known how the scatter compares with accuracy at present attained by forecasters in forecasting fog clearance, but preparation of diagrams of this type for various sites may help to prevent large errors. Perhaps the real significance of Fig. 2 is that it shows that a quite marked separation can be obtained by use of a simple parameter to represent vertical thickness of fog. This suggests that if measurements of depth of fog were available it might be possible to replace AA and BB by a series of curves representing different thicknesses of fog, and so increase the usefulness of the diagram as a forecasting tool.

It is emphasised that the cases included must be regarded as water fog, and that for many sites it will be necessary to distinguish between clean and heavily polluted fog.

Acknowledgment

It is desired to record the excellent and very detailed observing work carried out by the staff at Exeter during 1953-1955, especially by Mr. J. Meadows and Mr. N. R. Broadbear.

Reference

1. CORBY, G. A. and SAUNDERS, W. E. Water Fog Point, a further test. Met. Mag., London, 81, 1952, p.225.

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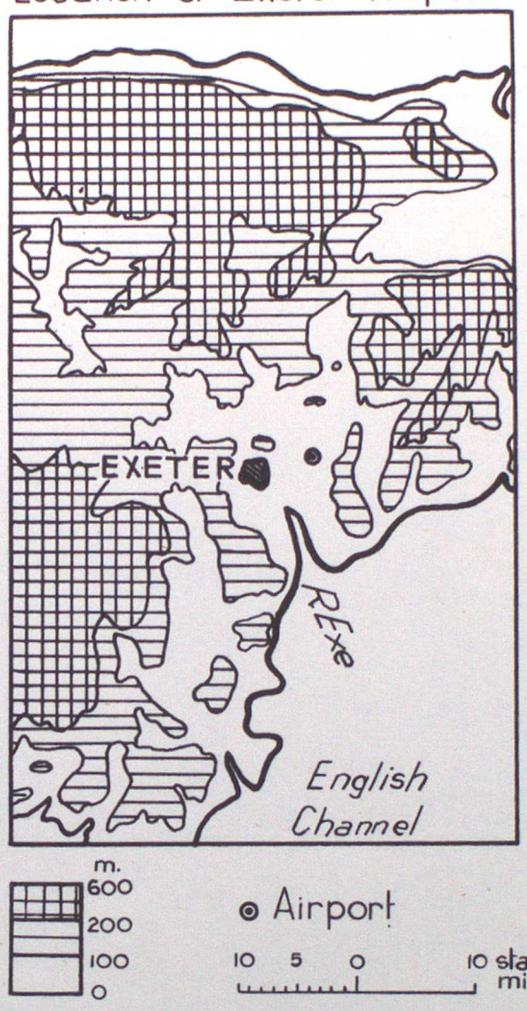
Fig. 1

Location of Exeter Airport



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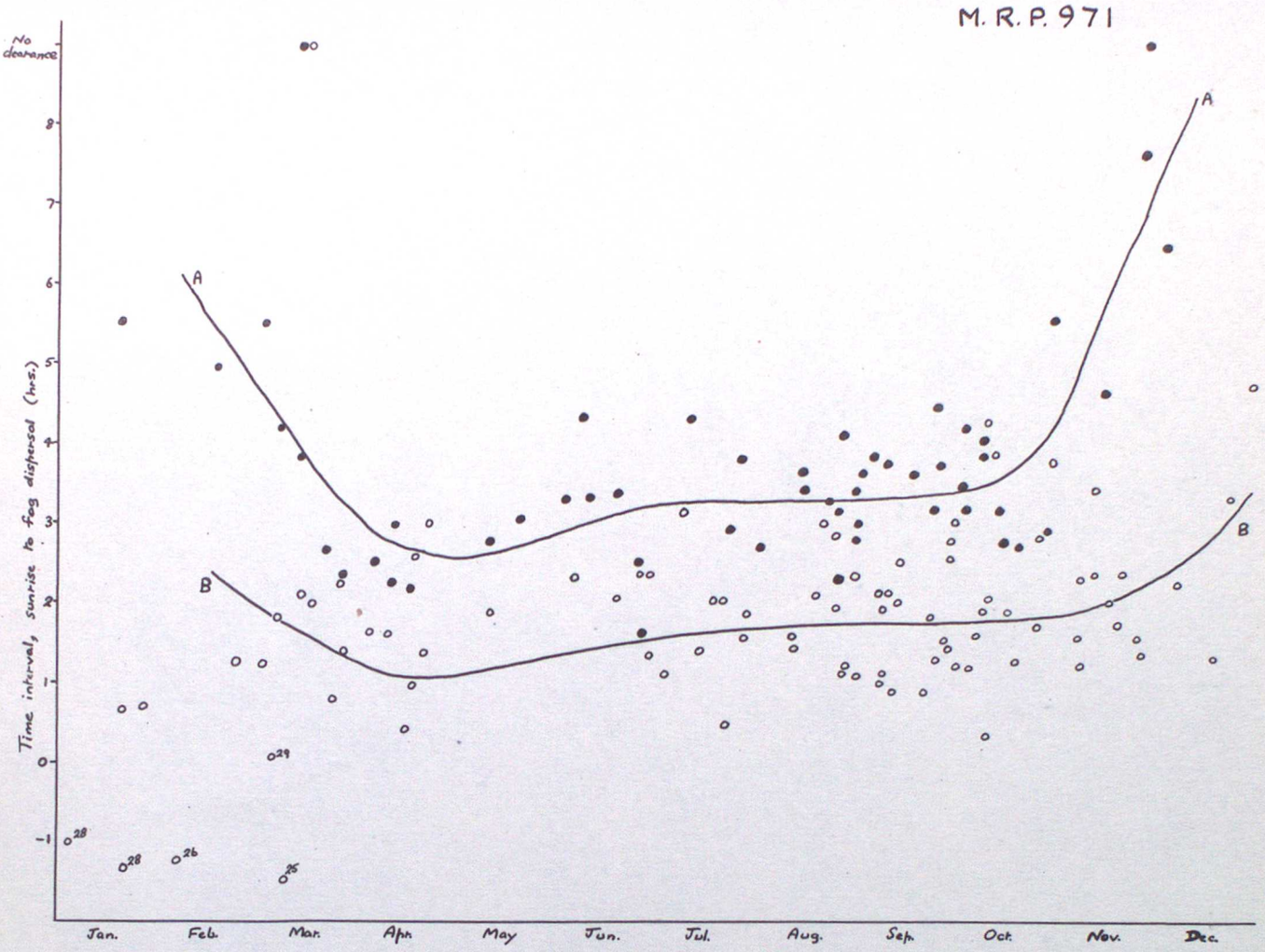

Fig. 2

Variation, with time of year, of time interval between sunrise and fog dispersal

● Cases of sky obscured reported at 0600 GMT

○ Cases of sky visible reported at 0600 GMT (the temperature of fog formation has been inserted beside the symbol if below 32°F)

AA and BB are curves drawn to fit cases ● and ○ respectively